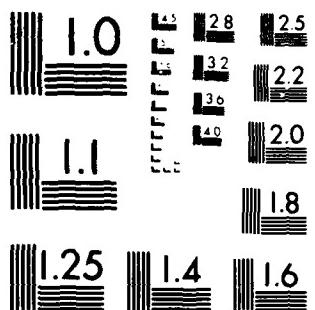


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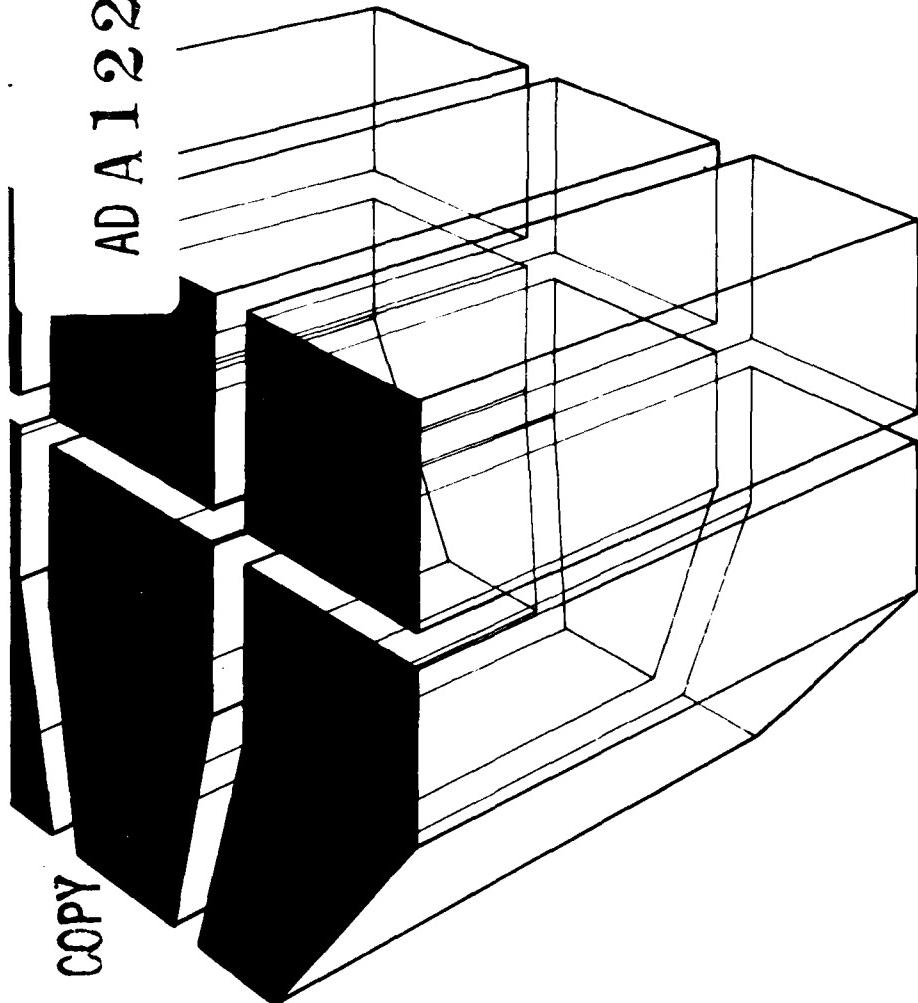
United States Army  
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Special Report P-138  
November 1982

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## COMPARISON OF UNIT COSTS FOR OPERATION AND MAINTENANCE OF BUILDINGS

ADA 122761



by  
Robert D. Neathammer  
Tibor Csizmadia

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)  Facility Operations and Maintenance data from Army, university, municipal, and private sectors were obtained and analyzed.  It was concluded that:		

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BLOCK 20. (CONT'd)

- o The O&M costs collected should be compared within geographical regions of the country and then with caution.
- o For administrative office-type buildings, the Army spends less than the private sector in all regions, with the Southern region being most comparable. For regions 1, 5, 6, and 7 (which have more than one installation), the differences range from \$.37 to \$1.37.
- o Army housing cost data is comparable to data for universities, especially for the southern region.
- o Over all buildings, the Army spends less than universities in all regions.
  - o Municipalities and private companies also spend more than the Army (based on a very small sample).

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## FOREWORD

This work was done for the Assistant Chief of Engineers under the reimbursable task, "Responsiveness Analysis of Military Programs (RAMP)." The technical monitor was Mr. Richard Nelson (DAEN-ZCF-R). The work was done by the Facility Systems (FS) Division, U.S. Army Construction Engineering Research Laboratory (CERL). Mr. E. A. Lotz is Chief of FS. Dr. L. R. Shaffer is Technical Director of CERL, and COL Louis J. Circeo is Commander and Director.

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## DISTRIBUTION

## **COMPARISON OF UNIT COSTS FOR OPERATION AND MAINTENANCE OF BUILDINGS**

### **Background**

The Office of the Chief of Engineers is interested in comparing operation and maintenance (O&M) unit costs of Army facilities to those in the university, municipal, and commercial sectors. This type of data is useful in presenting requirements and establishing unbiased comparisons of relative funding levels.

### **Objective**

The objective of this study was to gather and analyze comparable O&M data from the Army, university, municipal, and commercial sectors.

### **Approach**

O&M data from the various sectors were obtained for the past 2 years. The data were separated into operating costs and maintenance costs. For valid comparisons, data were separated by region of the country and comparative building types. Thus, military O&M data excluded family housing, hospitals, and ammunition storage facilities. University data were for housing and non-housing data separately. Municipality data excluded hospitals and stadiums/coliseums. Private sector data were primarily for office-type buildings.

### **Sources of Data**

Army -- "Annual Summary of Operations-Facilities Engineering" (known as the "Red Book"), published annually by the Office of the Chief of Engineers. This book contains O&M data for all Army installations and is given by installation. Appendix A gives the detailed analysis of this data. Twenty-two major installations were selected and data for fiscal years 1980 and 1981 were used.

Navy -- "Real Property Maintenance Activity Report PB-27." This lists O&M data Navy-wide, not by individual installation. No regionalization of this data was possible. See Appendix B for details.

Private sector 1 -- the Building Owners and Managers Association International (BOMA) publication (annual) "Downtown and Suburban Office Building Experience Exchange Reports." In addition, a special run was made by BOMA on certain 1980 data. (The 1981 data were not yet available.) See Appendix C for details.

Private sector 2 -- three private companies provided O&M data. Appendix D gives details.

Universities 1 -- the Association of Physical Plant Administrators (APPA) of Universities and Colleges publication "Comparative Costs and Staffing

Report" for school years 1979-80 and 1980-81. Data for 60 major institutions were extracted and analyzed. See Appendix E for details.

Universities 2 -- eleven universities were contacted and provided O&M data in more detail than given in the APPA reports. Appendix F summarizes this data.

Seven municipalities were contacted and provided the data analyzed in Appendix G.

### Results

Each appendix discusses data used and the assumptions made to apportion costs to building types for the military sectors, etc. Table 1 summarizes the results and gives O&M data for each region of the country. When using data in Table 1, note the small sample sizes for many of the costs.

For all buildings (except hospitals and housing) the Army and Navy spend less per square foot than universities and municipalities, with only a few exceptions. When only administrative/office buildings are considered, the private sector spends more. This is not unexpected, since the private sector must compete for customers and would be expected to spend more. For bachelor housing, the Army is generally close to the university sector.

### Problems in Comparing O&M Data

There are many problems in comparing O&M data from different sectors of facilities owners. Differences among and within these sectors result in data with certain biases, and these make meaningful, overall comparisons difficult, if not impossible. Reasons why overall comparisons for the various sectors are of little value are:

1. Geographic/climatic differences preclude direct comparison of operating costs. Energy costs for heating vary from north to south, as do costs for air conditioning. Thus, energy cost comparisons across climatic regions and/or regions of the country which have different unit energy costs should not be made. Geographic differences also occur for maintenance costs because of varying wage scales and amount of unionization of workers.

2. Accounting procedures vary across/within sectors. In some systems regular building maintenance is separated from renewal/replacement type work and in others is not kept separately. The Army keeps heating/air conditioning operating/maintenance costs in an account separate from the building O&M costs account serviced by the equipments. Thus, total O&M costs for an individual building or classification of building are not directly obtainable.

3. Maintenance policies/practices vary, since some places have a preventive maintenance program and some do not; some have a good inspection program, while others do not. Within the Army, maintenance policies/practices can vary from one major command to another and from one installation to another.

Table 1

## Summary of OfM Unit Costs (\$/Sq Ft)

BOMA Region	All Buildings (Nonhousing, Nonmedical)				Administrative/Office Bldgs				Bachelor Housing			
	Army	Navy*	APPA	Municipalities	Army	Navy*	BOMA**	Priv. Ind.	Army	Navy	Universities	
1	2.46(3)	2.36	3.03(7)	2.03(1)	3.58	2.76	4.72(29)	4.20(1)	2.80	—	—	
2	1.18(1)	2.36	2.28(12)	3.99(1)	1.66	2.76	4.42(24)	—	1.23	2.36(1)	—	
3	—	2.36	2.64(9)	3.34(1)	—	2.76	4.14(41)	3.36(2)	—	2.21(2)	—	
4	1.21(1)	2.36	2.10(5)	—	1.71	2.76	2.49(13)	—	2.48	2.83(1)	—	
5	1.77(3)	2.36	2.83(6)	—	2.63	2.76	4.00(41)	—	1.92	—	—	
6	1.82(10)	2.36	2.46(15)	3.08(2)	2.75	2.76	3.12(61)	—	2.04	2.18(4)	—	
7	1.33(4)	2.36	2.59(6)	—	2.07	2.76	3.44(52)	—	1.56	—	—	

The numbers in parentheses are the number of installations, universities, buildings (for BOMA) or companies on which the data are based.

\* Navy-wide average

\*\*BOMA data for suburban buildings less than 5 stories in height.

#### Definition of BOMA Regions

- 1 - Middle Atlantic: CT, DC, DE, MA, MD, ME, NH, NJ, NY, PA, RI, VT
- 2 - Midwest Northern: IA, KS, MO, MN, NB, ND, SD, WI
- 3 - North Central: IL, IN, MI, OH
- 4 - Pacific Northwest: AK, ID, MT, OR, WA, WY
- 5 - Pacific Southwest: AZ, CA, HI, NV, UT
- 6 - Southern: AL, FL, GA, KY, LA, MS, NC, SC, TN, VA, WV
- 7 - Southwest: AR, CO, NM, OK, TX

Note: The Army and Navy data are for the Federal Government, Fiscal Year 1981. BOMA data are for Calendar Year 1980, municipalities and private companies; or Calendar Year 1981 and universities for the school year 1980-81.

4. The Army has a "self-help" program in which building occupants are encouraged to perform some of their own maintenance. This can vary from changing a furnace filter or replacing a faucet washer to more complex electrical repairs (for troop units with qualified electricians). Labor costs for these repairs are not included in the accounting system.

5. In the military, in troop-occupied areas such as barracks and associated buildings (excluding dining halls), the troops perform custodial work and are responsible for their area. These costs are not reflected in the military cost accounting system.

6. Many military buildings are World War II vintage and considered temporary construction. In the university, municipal, and private sectors there may be old buildings, but they were usually built to be permanent and are more easily maintained and operated than a wooden 40-year-old non-insulated Army building.

7. Finally, the various sectors have different mixes and ages of buildings:

Military -- many troop housing buildings, family housing, or duplexes/apartments, administration buildings, training buildings, hospitals, medical buildings, tank/automotive/weapons maintenance buildings, research/development buildings, and some production type buildings.

Universities -- mostly classrooms and laboratories, many dormitories, and some special-purpose types.

Municipalities -- office buildings, court house buildings, hospitals, jails, maintenance shops, stadiums/coliseums, etc.

Private companies -- buildings reflecting their business. They can be all of one type or a mix of offices (e.g., maintenance, manufacturing, laboratory, etc.).

#### Conclusions

- O&M costs should only be compared within geographical regions of the country and then with caution.
- For administrative office-type buildings, the Army spends less than the private sector in all regions, with the Southern region being most comparable. For regions 1, 5, 6, and 7 (which have more than one installation), the differences range from \$.37 to \$1.37.
- Army housing cost data are comparable to data for universities, especially for the Southern region.
- Over all buildings, the Army spends less than universities in all regions.
- Municipalities and private companies also spend more than the Army (based on a very small sample).

APPENDIX A  
O&M Costs For Army Facilities

The source for O&M cost data for Army facilities is the "Red Book" -- Facilities Engineering Annual Summary of Operations published yearly by the Office of the Chief of Engineers. Data is reported for each Army installation by the Army Management Structure code. Data for FY80 and FY81 were analyzed for the 22 installations listed in Table A1.

Table A1  
List of Army Installations

Ft. Benning, GA	Ft. Huachuca, AZ	Ft. Riley, KS
Ft. Bliss, TX	Ft. Jackson, SC	Ft. Rucker, AL
Ft. Bragg, NC	Ft. Knox, KY	Ft. Sam Houston, TX
Ft. Campbell, KY	Ft. Lee, VA	Ft. Sill, OK
Ft. Devens, MA	Ft. Lewis, WA	Ft. Stewart, GA
Ft. Dix, NJ	Ft. Meade, MD	White Sands Missile
Ft. Eustis, VA	Ft. Ord, CA	Range, NM
Ft. Hood, TX	Ft. Polk, LA	

These were selected for their size and geographical location.

O&M costs were calculated for non-medical and non-housing type buildings, since medical and housing-type buildings are not included in the APPA, BOMA, and municipality data. Also, barracks housing O&M data were calculated separately to compare with the university dormitory data obtained from universities. O&M costs were also computed for administration-type buildings for more direct comparison to BOMA and municipality data.

Maintenance Costs

The Red Book lists maintenance costs for several types of buildings and for several installation-wide types of heating/cooling equipment and utilities as shown in Table A2. (Maintenance costs for ammunition storage facilities and utility plant buildings were excluded from the analyses.)

Total maintenance unit costs (\$/sq ft) for an installation were obtained by:

Summing the building maintenance costs (excluding medical and housing)  
Pro-rating most utility, heating, cooling costs by the percent area  
represented by the nonmedical, nonhousing buildings.

Table A2  
Operating and Maintenance Cost Accounts

MAINTENANCE

Training Bldgs (K2100 Account)	Water systems (K1100)
Maintenance/Production Bldgs (K2200)	Sewage Systems (K1200)
RDTE Bldgs (K2300)	Electric Systems (K1300)
Other Covered Storage (K2420)	Boiler Plants, High Pressure (K1410)
Hospital/Medical Bldgs (K2500)	Heating Plants, Over 3.5 MBTU-HR (K1420)
Administration Bldgs (K2600)	Heating Plants, .75-.3.5 MBTU-HR (K1430)
Bachelor Housing (K2700)	Heating Plants, Under .75 MBTU-HR (K1440)
Community Bldgs (K2800)	Steam/Hot Water Distr Systems (K1451)
Family Housing (K2910)	Gas Distribution System (K1452)
Operational Bldgs (K2920)	Gas Storage/Generating (K1453)
Other Bldgs (K2930)	Air Conditioning Plants, Over 100 Tn (K4511)
	Air Conditioning Plants, 26-100 Tn (K1512)
	Air Conditioning Plants, 5-26 Tn (K1513)
	Air Conditioning Plants, Under 5 Tn (K1514)
	Improved Grounds (K3100)

OPERATING

Water Service (J1000 account)	Purchased Steam and Hot Water (J4500)
Sewage Service (J2000)	Air Conditioning Plants, Over 100 Tn (J5100)
Electric Service (J3000)	Air Conditioning Plants, 26-100 Tn (J5200)
Boiler Plants, High Pressure (J4100)	Air Conditioning Plants, Under 26 Tn (J5300)
Heating Plants, Over 3.5 MBTU-HR (J4200)	Refuse Handling (M2000)
Heating Plants, .75-.3.5 MBTU-HR (J4300)	Peat Control (M3000)
Heating Plants, Under .75 MBTU-HR (J4400)	Custodial Services (M4000)
	Maintenance and Engineering (M6100)

For heating plants under .75 Btu-hr and air conditioning units under 5 tons, 10 percent of their maintenance costs were included. (Small units such as these are normally found in family housing areas --- it was assumed 90 percent of these units would be in such areas.)

Thus, an adjusted maintenance cost was found for each installation. These costs are shown for each installation in Table A3.

#### Operating Costs

Operating costs shown in Table A2 were taken from the Red Book. As for maintenance work above, the operating cost data was adjusted to delete medical and housing costs. This was done as follows:

All costs except heating and electricity were apportioned by percent of area

Costs for heating and electricity were apportioned by factors developed from results of prior CERL research<sup>1</sup> -- family housing (FH) uses about .75 times its percentage of area of the electricity on a post. If FH occupies 15 percent of the total building area, then it uses about  $.75 \times 15\% = 10.2\%$  of total electricity on post. Similarly, for heating, FH uses .95 times its area or in the example,  $.95 \times 15\% = 14.2\%$  of heating costs.

The operating costs are shown for each installation in Table A3.

#### O&M Costs -- Administration Buildings and Bachelor Housing

O&M costs were also computed separately for administrative buildings and bachelor housing to allow comparisons to (a) BOMA and municipality, and (b) university housing data, respectively.

Table A4 shows these costs for each installation.

#### Geographical Effects

From the tables discussed above, it is obvious that O&M costs vary widely across installations. No one average cost can truly represent Army O&M costs.

A more realistic approach is to group installations by region and summarize costs for each region. Nine regions were used; Table A5 shows the cost data by region.

<sup>1</sup> B. J. Sliwinski, D. Leverenz, L. Windingland, A. Mech, Fixed Facilities Energy Consumption Investigation -- Data Analysis, Interim Report E-143/ADA066513 (CERL, 1979).

Table A3

**Adjusted Operating and Maintenance  
Costs (\$/Sq Ft) for 22 Army Installations**

<u>Installation</u>	<u>Operating</u>		<u>Maintenance</u>		<u>Total</u>	
	<u>FY80</u>	<u>FY81</u>	<u>FY80</u>	<u>FY81</u>	<u>FY80</u>	<u>FY81</u>
Ft. Bragg	1.52	1.97	.16	.13	1.68	2.10
Ft. Campbell	1.20	1.40	.11	.10	1.31	1.50
Ft. Devens	1.29	1.69	.15	.16	1.44	1.85
Ft. Hood	1.01	1.28	.15	.19	1.16	1.47
Ft. Sam Houston	.91	.97	.28	.23	1.19	1.20
Ft. Lewis	1.02	1.11	.20	.09	1.22	1.20
Ft. Meade	2.09	2.30	.30	.26	2.39	2.56
Ft. Ord	1.20	1.00	.15	.10	1.35	1.10
Ft. Polk	.83	1.16	.15	.13	.98	1.29
Ft. Riley	.90	1.03	.10	.14	1.00	1.17
Ft. Stewart	1.13	1.44	.21	.26	1.34	1.70
Ft. Benning	1.30	1.50	.28	.40	1.58	1.90
Ft. Bliss	.93	1.22	.19	.17	1.12	1.39
Ft. Dix	2.18	2.71	.17	.26	2.35	2.97
Ft. Eustis	1.59	2.20	.34	.41	1.93	2.61
Ft. Jackson	1.28	1.58	.23	.28	1.51	1.86
Ft. Knox	1.10	1.12	.21	.21	1.22	1.33
Ft. Lee	1.62	1.72	.23	.27	1.85	1.99
Ft. Rucker	1.34	1.56	.30	.36	1.64	1.92
Ft. Sill	.84	.90	.29	.35	1.13	1.25
Ft. Huachuca	1.32	1.40	.36	.29	1.68	1.69
WSMR	1.70	2.19	.27	.35	1.97	2.54

Table A4

## Administration Buildings and Bachelor Housing O&amp;M Costs (\$/Sq Ft)

Administration

Installation	Operating		Maintenance		Total	
	FY80	FY81	FY80	FY81	FY80	FY81
Ft. Bragg	1.52	1.97	1.09	.92	2.61	2.89
Ft. Campbell	1.20	1.40	.93	1.10	2.13	2.50
Ft. Devens	1.29	1.68	.56	.82	1.85	2.50
Ft. Hood	1.01	1.28	.82	.99	1.83	2.27
Ft. Sam Houston	.91	.97	1.40	.79	2.31	1.76
Ft. Lewis	1.02	1.11	.85	.59	1.87	1.70
Ft. Meade	2.09	2.30	1.51	1.50	3.60	3.80
Ft. Ord	1.20	1.00	.72	.65	1.92	1.65
Ft. Polk	.83	1.16	.86	.76	1.69	1.92
Ft. Riley	.90	1.03	.54	.63	1.44	1.66
Ft. Stewart	1.13	1.44	.64	1.07	1.77	2.51
Ft. Benning	1.30	1.50	1.66	1.65	2.96	3.15
Ft. Bliss	.93	1.22	.91	.83	1.84	2.05
Ft. Dix	2.18	2.71	.88	1.72	3.06	4.43
Ft. Eustis	1.59	2.20	1.18	1.54	2.77	3.74
Ft. Jackson	1.28	1.58	1.04	1.34	2.32	2.92
Ft. Knox	1.10	1.12	1.09	1.03	2.10	2.15
Ft. Lee	1.62	1.72	.80	1.35	2.42	3.07
Ft. Rucker	1.34	1.56	1.15	1.08	2.49	2.64
Ft. Sill	.84	.90	1.02	1.28	1.86	2.18
Ft. Huachuca	1.32	1.40	1.85	1.70	3.17	3.10
WSMR	1.70	2.19	1.32	.96	3.02	3.15

Bachelor Housing

Installation	Operating		Maintenance		Total	
	FY80	FY81	FY80	FY81	FY80	FY81
Ft. Bragg	.88	1.12	.55	.56	1.43	1.68
Ft. Campbell	.62	.72	.65	.71	1.27	1.43
Ft. Devens	.90	1.16	.76	.86	1.66	2.02
Ft. Hood	.55	.71	.63	.95	1.18	1.66
Ft. Sam Houston	.63	.68	.98	.82	1.61	1.50
Ft. Lewis	.70	.76	.74	.71	1.44	1.47
Ft. Meade	1.30	1.45	1.61	1.55	2.91	3.00
Ft. Ord	.77	.62	.54	.51	1.31	1.13
Ft. Polk	.53	.72	.83	.78	1.36	1.50
Ft. Riley	.52	.59	.62	.65	1.14	1.24
Ft. Stewart	.74	.89	.81	.92	1.55	1.81
Ft. Benning	.79	.91	.66	.96	1.45	1.87
Ft. Bliss	.62	.81	.73	.63	1.35	1.44
Ft. Dix	1.41	1.74	.81	1.63	2.22	3.37
Ft. Eustis	1.06	1.42	1.02	1.54	2.08	2.96
Ft. Jackson	.80	.99	.85	.93	1.65	1.92
Ft. Knox	.68	.75	.83	.90	1.51	1.65
Ft. Lee	1.06	1.12	1.26	1.95	2.32	3.07
Ft. Rucker	.91	1.08	1.23	1.40	2.14	2.48
Ft. Sill	.58	.63	.91	1.02	1.49	1.65
Ft. Huachuca	.92	1.01	.97	1.08	1.89	2.09
WSMR	1.32	1.69	1.20	.84	2.54	2.53

**Table A5**  
**O&M Cost Data by Geographic Region**

**a. Adjusted Overall O&M Costs**

<u>Region</u>	<u>No. Install</u>	<u>Operating</u>		<u>Maintenance</u>		<u>Total</u>	
		<u>FY80*</u>	<u>FY81*</u>	<u>FY80</u>	<u>FY81</u>	<u>FY80</u>	<u>FY81*</u>
1	3	.92	1.05	.24	.26	1.16	1.31
2	3	1.15	1.41	.24	.30	1.39	1.71
3	3	1.31	1.66	.20	.22	1.51	1.88
4	2	1.61	1.96	.29	.34	1.90	2.30
5	3	1.04	1.19	.14	.15	1.18	1.34
6	3	1.85	2.23	.21	.23	2.06	2.46
7	3	1.31	1.60	.28	.27	1.59	1.87
8	1	1.52	1.11	.20	.09	1.22	1.20
9	1	1.10	1.00	.15	.10	1.35	1.20

**b. Administration Buildings**

<u>Region</u>	<u>No. Install</u>	<u>Operating</u>		<u>Maintenance</u>		<u>Total</u>	
		<u>FY80</u>	<u>FY81*</u>	<u>FY80</u>	<u>FY81</u>	<u>FY80</u>	<u>FY81*</u>
1	3	.92	1.05	1.09	1.02	2.01	2.07
2	3	1.15	1.41	1.22	1.16	2.37	2.57
3	3	1.31	1.66	.92	1.11	2.23	2.77
4	2	1.61	1.96	.99	1.44	2.60	3.40
5	3	1.04	1.19	.85	.92	1.89	2.11
6	3	1.85	2.23	.98	1.35	2.83	3.58
7	3	1.31	1.60	1.36	1.16	2.67	2.76
8	1	1.02	1.11	.85	.59	1.26	1.70
9	1	1.20	1.00	.72	.65	1.92	1.65

**c. Bachelor Housing**

<u>Region</u>	<u>No. Install</u>	<u>Operating</u>		<u>Maintenance</u>		<u>Total</u>	
		<u>FY80*</u>	<u>FY81*</u>	<u>FY80</u>	<u>FY81*</u>	<u>FY80</u>	<u>FY81*</u>
1	3	.59	.67	.84	.93	1.43	1.60
2	3	.74	.90	.91	1.05	1.65	1.95
3	3	.81	1.00	.74	.80	1.55	1.80
4	2	1.06	1.27	1.14	1.74	2.20	3.01
5	3	.61	.69	.70	.75	1.31	1.44
6	3	1.20	1.45	1.06	1.35	2.26	2.80
7	3	.96	1.17	.96	.85	1.92	2.02
8	1	.70	.76	.74	.71	1.44	1.47
9	1	.77	.52	.54	.51	1.31	1.13

\*Indicates statistically significant differences among regions.

Note that the regional costs for adjusted overall O&M costs are relatively more homogeneous; i.e., there is an averaging-out effect when looking at large gross building areas for several types of buildings. But for administration buildings and bachelor housing, the regional costs vary more -- as much as \$1.93/sq ft for the former and \$1.88/sq ft for the latter.

These regions were defined differently from the BOMA regions used in Table 1 and in analyzing BOMA and APPA data. The nine regions were as follows:

- 1 - Southwest: Ft. Hood, Ft. Sill, Ft. Sam Houston
- 2 - South: Ft. Polk, Ft. Benning, Ft. Rucker
- 3 - Southeast: Ft. Stewart, Ft. Bragg, Ft. Jackson
- 4 - East: Ft. Lee, Ft. Eustis
- 5 - Midwest: Ft. Campbell, Ft. Knox, Ft. Riley
- 6 - North Atlantic: Ft. Dix, Ft. Devens, Ft. Meade
- 7 - Desert: Ft. Huachuca, Ft. Bliss, WSMR
- 8 - Pacific NW: Ft. Lewis
- 9 - Pacific SW: Ft. Ord

It was believed these regions might prove more discriminating than the BOMA ones.

Operating costs, maintenance costs, and total O&M costs in Table A5 were compared across regions for each of overall, administration, and bachelor facilities for each year.

Statistically significant differences (95 percent confidence level) were found among regions for:

Overall adjusted operating costs for each year  
Administration building operating costs for FY81  
Bachelor housing operating costs for each year  
Bachelor housing maintenance costs for FY81  
Bachelor housing and administration costs for FY81  
Total O&M costs for 1981

APPENDIX B  
O&M Costs for Naval Facilities

O&M costs were taken from the FY80 and FY81 Real Property Maintenance Activity reports PB-27 dated 9 Jan 81 and 13 Jan 82 respectively. These reports list O&M expenditures Navy-wide excluding Naval Industrial Funded Activities and reserve centers. The areas for various facility classes were obtained from the Navy Real Property Inventory report. These areas were for FY81 but should also be appropriate for use with FY80 cost data.

Table B1 shows the maintenance costs for facility classes and for heating/cooling units, water distribution, etc. Note family housing is not included in the data. Table B2 gives operating costs Navy-wide.

Overall Maintenance Costs

Nonmedical and nonhousing facilities represent 73.8 percent of the area of the buildings. The maintenance costs for heating, air conditioning, utilities and miscellaneous were apportioned by area (costs in thousands):

$$\begin{aligned}1980: .738 \times (43323 + 32987) &= 56317 \\1981: .738 \times (41933 + 38882) &= 59641\end{aligned}$$

The total maintenance costs are then:

$$\begin{aligned}1980: 56317 + (129764 - 18812 - 24187 - 6791) &= 136291 \\1981: 59641 + (174863 - 23990 - 39241 - 9576) &= 161647\end{aligned}$$

Using 166,694,000 sq ft gives 1980 = \$.82/sq ft

$$1981 = \$.97/\text{sq ft}$$

Overall Operating Costs

Operating costs were also apportioned by area except for electricity and heating. The following percents of total usage are based on data from the CERL Technical Report E-143.

	<u>Electricity</u>	<u>Heating</u>
Communication/admin/training/RDTE	17%	12%
Storage	3	7
Community	<u>22</u>	<u>10</u>
	42%	29%

**Table B1**  
**Recurring and Nonrecurring Maintenance Costs**

<u>Type Facility</u>	<u>FY1980 (x \$1000)</u>	<u>FY1981 (x \$1000)</u>	<u>Area (x 1000 sq ft)</u>
<u><b>Buildings</b></u>			
Communications (71K0)	3692	5989	3715
Training (7110)	10127	13520	22839
RDTE (7130)	927	571	3337
Storage (7140)	15350	23164	62556
Medical (7150)	18812	23990	13358
Administration (7160)	20999	23375	24840
Bachelor EM Housing (7170)	24187	39291	35356
Bachelor Housing Mess (7180)	5515	7519	2777
BOQ's (71A0)	6791	9576	7704
Community (71J0)	<u>23364</u>	<u>27868</u>	<u>49407</u>
	129764	174863	225889
<u><b>Heating and Air Cond. and Utilities</b></u>			
Air Cond 25-100 Tn (76A0)	6212	6069	
Air Cond 5-25 Tn (76B0)	3492	4021	
Air Cond Over 100 Tn (76G0)	6741	4503	
Heating Over 3.5 MBTU (7620)	3326	4518	
Heating .75-3.5 MBTU (7630)	1484	1834	
Electrical (7710)	10824	11236	
Steam and Hot Water (7720)	6268	4589	
Potable Water Distr. Fac (7730)	1286	1197	
Potable Water Distr. (7740)	2313	2118	
Sewage and Indust. Waste (7760)	1308	1727	
Gas Distr. Sys. (7770)	<u>69</u>	<u>121</u>	
	<u>43323</u>	<u>41933</u>	
<u><b>Miscellaneous</b></u>			
Grounds (7410)	13479	14978	
Semi-Improved Grounds (7430)	2632	3803	
Preventive Maint. Inspec. (9280)	8697	8971	
Other Maintenance (9290)	<u>8179</u>	<u>10230</u>	
	<u>32987</u>	<u>38882</u>	
<b>Totals</b>	<b>206074</b>	<b>255678</b>	

Table B2

## Operating Costs (x \$1000)

<u>Description</u>	<u>FY80</u>	<u>FY81</u>
Steam and Hot Water .75 - 3.5 MBTU (8100)	11062	14602
Steam and Hot Water Over 3.5 MBTU (8200)	103031	127461
Electricity (8300)	159350	236451
Potable Water (8400)	19102	19182
Sewage (8500)	11349	12415
Air Conditioning (8600)	5300	6690
Other Utility Systems (8700)	10309	10212
Fuels for Heating Plant under .75 MBTU (87H0)	7630	7602
Custodial In-House (9210)	24127	23144
Custodial Contract (92E0)	23503	22960
General Shop Overhead (92A0)	6687	9830
Pest, Weed Control (9220)	4893	5946
Refuse/Garbage Disposal (9230)	<u>13766</u>	<u>13995</u>
Total without Electricity and Heating	119036	124374

Nonmedical and nonhousing operating costs (x \$1000) are then:

$$1980: .738 \times 119036 + .42 (159350) + .29 (11062 + 103031 + .1 \times 7630*) = 188084$$

$$1981: .738 \times 124374 + .42 (236451) + .29 (14602 + 127461 + .1 \times 7602*) = 232516$$

\*90% of costs for small heating units is allocated to housing

Using 166,694,000 sq ft gives 1980 = \$1.13/sq ft  
1981 = \$1.39/sq ft

#### Total O&M Costs for Nonhousing, Nonmedical

1980 = \$1.95/sq ft  
1981 = \$2.36/sq ft

for nonmedical, nonhousing facilities.

#### Administration Buildings

Maintenance costs (x \$1000) for administration buildings (includes communication, training and RDTE buildings) were computed as follows. They represent 54,731,000 sq ft or 24.2 percent of the total area.

$$1980: 35745 + .242 (43323 + 32987) = 54212 \text{ or } \$0.99/\text{sq ft}$$

$$1981: 44070 + .242 (41933 + 38882) = 63627 \text{ or } \$1.16/\text{sq ft}$$

Operating costs were calculated as shown below:

$$1980: .242 \times 119036 + .17 (159350) + .12 (11062 + 103031 + .1 \times 7630) = 69679 \\ \text{or } \$1.27/\text{sq ft}$$

$$1981: .242 \times 124374 + .17 (236451) + .12 (14602 + 127461 + .1 \times 7602) = 87434 \\ \text{or } \$1.60/\text{sq ft}$$

Total O&M costs are: 1980 = \$2.26/sq ft  
1981 = \$2.76/sq ft

Several types of buildings were grouped together because no separate estimate of electricity/heating use was available.

## APPENDIX C

### Building Owners and Managers Association (BOMA) International Data

The BOMA publishes an annual "Downtown and Suburban Office Building Experience Exchange Report" which contains income and expenditure data in cents per square foot of office and retail space. In this study, data from 1979 and 1980 were analyzed. Statistical analyses were performed to evaluate regional, building age, and inflation effects on operating and maintenance costs. Only data from suburban buildings were used in the analyses as these would be more comparable to Army posts' data than downtown locations.

#### Regional and Inflation Differences

Table C1 shows the 1979 and 1980 data for five types of maintenance costs and for energy costs for seven regions. An analysis was performed for each cost type and for total costs to determine if there is a statistically significant difference between regions or years. In most cases, the cost increased from 1979 to 1980. For those asterisked, the cost decreased.

Regional differences were found for cleaning costs, HVAC costs and energy costs. A significant increase from 1979 to 1980 was found only for energy costs.

#### Age Differences

Table C2 gives data for different building ages. These were suburban buildings over all regions. Because there were so few samples in the 20-29 years group for 1979, only the 0-9 and 10-19 years groups were compared for 1979. All three groups were compared for the 1980 data to determine if statistically significant differences exist.

For the 1979 data, the differences between the two age groups were not statistically significant.

For the 1980 data, the differences among the three age groups were statistically significant.

#### Limited Sample Analysis

Only suburban buildings less than or equal to 4 stories in height were compared in this analysis. The data is shown in Table C3.

Table C1

Maintenance and Energy Costs by Region and Data Collection  
Year For Suburban Buildings (\$/Sq Ft)

<u>Region</u>	<u>Cleaning</u>		<u>Electrical</u>		<u>HVAC</u>		<u>General</u>		<u>Administration</u>		<u>Energy</u>		<u>Total</u>
	<u>79</u>	<u>80</u>	<u>79</u>	<u>80</u>	<u>79</u>	<u>80</u>	<u>79</u>	<u>80</u>	<u>79</u>	<u>80</u>	<u>79</u>	<u>80</u>	
Middle Atlantic	.67	.71	.13	.16	.31	.32	.82	.52	.33	.44	1.60	1.47	*3.66
Midwest Northern	.62	.80	.07	.10	*.28	.26	.62	.68	.37	.79	1.12	1.30	3.09
North Central	.88	.93	.12	.17	.32	.37	.72	.87	.39	.54	1.16	1.31	3.58
Pacific NW	.71	.80	.04	.07	.07	.07	.11	*.27	.96	*.77	.71	.40	3.27
Pacific SW	*.98	.82	*.13	.09	.19	.21	.72	.76	.40	.62	1.34	1.56	3.76
Southern	.52	.62	.08	.17	.17	.18	.52	.53	.34	.39	.96	1.25	2.61
Southeast	.56	.61	.07	.16	.23	.26	*.72	.53	.33	.39	1.21	1.21	3.17

\*Cost decreased from 1979 to 1980.

NOTE: 1979 data taken from pp. 66-72 of the 1980 BOMA report  
1980 data taken from pp. 64-70 of the 1981 BOMA report

Sample sizes varied as follows:

1979 - from 20-94 buildings except Pacific NW which had 4-8 buildings for the six costs.  
1980 - from 31-88 buildings for regions other than Pacific NW which had 10-18 buildings for the six costs.

Table C2

**Maintenance and Energy Costs by Building Age  
and Data Collection Year (\$/Sq Ft)**

<u>Type Maintenance or Energy Cost</u>	<u>1979 Data</u>			<u>1980 Data</u>				
	<u>Building Age</u>	<u>0-9 yrs</u>	<u>10-19</u>	<u>20-29</u>	<u>Building Age</u>	<u>0-9</u>	<u>10-19</u>	<u>20-29</u>
Cleaning		.63	.75	1.09		.70	.77	.94
Electrical		.08	.11	.35		.13	.16	.17
HVAC		.24	.25	.37		.26	.29	.37
General Bldg.		.64	.78	1.66		.63	.63	.81
Administration		.36	.34	.40		.52	.46	.50
Energy		1.15	1.28	.71		1.28	1.36	1.53
Total		3.12	3.54	4.30		3.61	3.54	4.01

NOTE: 1979 data from pp. 77-79 of the 1979 BOMA report.  
1980 data from pp. 75-78 of the 1980 BOMA report.

Sample sizes varied as follows:

1979 Data: 0-9 yr; 204-244 buildings  
10-19; 63-87 buildings  
20-29; 3-6 buildings

1980 Data: 0-9 yrs; 246-269 buildings  
10-19; 83-125 buildings  
20-29; 16-20 buildings

Table C3

	<u>1979 Data</u>	<u>1980 Data</u>
Cleaning	.71	.77
Electrical	.12	.16
HVAC	.27	.28
General Building	.77	.84
Administration	.44	.56
Energy	1.17	1.34

Data for 1979 were taken from p. 83 of the 1979 BOMA report and data for 1980 were taken from p. 81 of the 1980 report. Sample sizes varied from 154-186 for the 1979 data and from 199-243 for the 1980 data.

The increases from 1979 to 1980 were statistically significant.

To examine this type of data more closely BOMA made a special computer run to generate 1980 data for suburban buildings less than or equal to 4 stories in height by region. This data is shown in Table C4. Analysis of this data showed significant differences among regions.

Note especially the total column. O&M costs range from \$2.49/sq ft in the Pacific Northwest to \$4.72/sq ft in the Middle Atlantic region.

#### Summary

1. Regional differences greatly affect cost data. This means no one figure can be given as a nationwide average for O&M costs.
2. O&M costs increase with the age of buildings but the increases are small compared to regional differences. This increase occurs mainly after 20 years of age.

Table C4

1980 Data for Suburban Buildings Less  
than Five Stories, by Region

<u>Region</u>	<u>No. Bldgs.</u>	<u>Type O&amp;M Cost</u>				<u>Total*</u>
		<u>Cleaning</u>	<u>Electrical</u>	<u>HVAC</u>	<u>General</u>	
Middle Atlantic	29	.80	.16	.29	1.14	.47
North Central	41	.88	.16	.36	.91	.62
Midwest Northern	24	.94	.21	.31	.87	.79
Pac Northwest	13	.80	.08	.21	.37	.32
Pac Southwest	41	.97	.14	.22	.87	.74
Southwest	52	.69	.08	.29	.76	.50
Southern	61	.62	.23	.16	.51	.44

\*Total costs include elevator maintenance.

## APPENDIX D

## Private Sector -- Selected Sample O&amp;M Costs

Of nine private companies contacted, three provided O&M cost data for their buildings. One was a small office building, one a large manufacturing complex and one a complex of offices and retail space. Other companies contacted could not provide the data as desired or declined to provide any.

	<u>Company A</u> (Ohio)	<u>Company B</u> (Illinois)	<u>Company C</u> (New York)
No. Buildings	2	12	13
Area (sq ft)	434800	4620300	4179852
Administrative	\$.61	.45	.27
Janitorial	\$.76	.15	1.38
Bldg Maint	\$.75	.56	1.03
Renewal/Replacement	\$.38	NA	.44
Grounds Maint	NA	.10	.04
Gas	\$.22	.12	--
Electricity	\$1.37	13.03*	1.04
Total	\$4.09	2.63	4.20

\*Most electricity used in manufacturing process -- \$1.25 used to compute total

## APPENDIX E

### Universities' O&M Cost Data -- from APPA Reports

Data for 60 universities were extracted from the two APPA reports for 1979-80 and 1980-81 school years. There are six categories of costs:

- Administrative
- Engineering
- Building maintenance
- Custodial
- Grounds
- Utilities

The 60 sets of data were classified into geographical regions using the BOMA regions.

Table E1 summarizes the 1980-81 data by region. Statistical analyses were run on the differences (1980-81 minus 1979-80) for each of the six O&M types and for total O&M costs. Only utilities cost was statistically significant. Note the wide range in total O&M costs for each region. Large variation within regions is one reason why regional differences are not significant.

Thus one might conclude that smaller, more homogenous regions are needed or that the variation between universities is just inherently large. The latter has some validity as total 1980-81 costs for:

- two schools from Pennsylvania were \$1.97 and \$2.76,
- two schools from Nebraska were \$1.67 and \$2.29,
- two schools from Illinois were \$2.03 and \$4.17,
- two schools from Missouri were \$1.86 and \$3.02,
- and two schools from California were \$2.47 and \$3.71.

Such differences are partly due to location -- urban or rural. When using a regional or even state average, care must be taken when applying such figures to another situation.

The above analysis demonstrates the difficulty in developing gross O&M costs.

Table E1

## Summary of Universities' O&amp;M Costs (\$/Sq Ft) -- from APPA Reports)

Region	No. Univ	Administrative	Engineering	Building Maintenance	Custodial	Grounds	Utilities	Total O&M	Range of Values for Total O&M
1--Middle Atlantic	7	.11	.07	.48	.64	.21	1.55	3.03	1.97 - 4.19
2--Midwest Northern	12	.08	.04	.47	.61	.10	.98	2.28	1.67 - 3.11
3--North Central	9	.07	.03	.53	.58	.15	1.28	2.64	1.86 - 4.17
4--Pacific Northwest	5	.08	.04	.60	.50	.12	.75	2.10	1.62 - 2.57
5--Pacific Southwest	6	.10	.14	.55	.62	.23	1.21	2.83	1.22 - 3.71
6--Southern	15	.12	.04	.53	.56	.13	1.08	2.46	1.64 - 3.07
7--Southwest	6	.12	.16	.50	.48	.13	1.28	2.59	2.10 - 3.37

## APPENDIX F

### Universities' O&M Data -- Selected Sample

Nine universities provided more detailed data in response to a request from CERL. Data were requested on heating/air conditioning plants as well as general categories, but too little was received for analysis.

Data were requested for the following categories of O&M:

- Administrative
- Janitorial
- Building maintenance
- Renewal/replacement
- Grounds maintenance
- Purchased gas
- Purchased electricity
- Generated electricity
- Central heating plants

It was found some universities do not have data readily broken down into these categories. The data are shown in Table F1.

The final column of Table F1 is the total O&M costs found from submitted data and the total cost obtained from adding the category costs of the APPA reports. It is obvious that the method of breaking out costs affects the final total. These survey data were not used in Table 1, which compares all sectors.

The data above were for nonhousing buildings. Data were also received from nine universities (not necessarily the same ones) for student housing. These data are shown in Table F2. Note the relative homogeneity of these data across regions. The Alabama data were not used further because of its very small area of housing and small janitorial costs.

Table F1  
Universities' O&M Costs (\$/Sq Ft) Provided to CERL

Region (BOMA)	State Area	Building Area (Sq ft)	Administrative	Janitorial	Building Maint.	Renewal/ Replacement	Grounds Maint.	Purch. Gas/ Elect.	Central Heating	Oper.	Maint.	Total O&M
3 IL	3501384	.14	.52	.47	.02	.22	1.10	.43	1.53	1.37	2.90	(2.03)
3 IL	8742770	.06	.56	.66	.09	.16	.59	.74	1.43	1.53	2.96	(2.76)
3 IN	5104540	.32	.62	.50	--	.18	.92	.68	1.60	1.63	3.23	(1.86)
4 WA	9800000	.15	.49	.77	1.02	.11	.22	.31	.53	2.54	3.07	(1.93)
6 FL	3024873	.21	.73	.62	.27	.31	1.53	.60	2.13	2.14	4.27	(2.98)
6 GA	4918509	.13	.55	.30	.23	.19	.54	.49	1.03	1.40	2.44	(2.14)
6 NC	2370000	.68	.92	.59	.81	.36	.93	.20	1.14	3.36	4.49	(3.66)
6 SC	4622478	.10	.29	1.05	--	.14	.42	.22	.64	1.58	2.22	(1.83)
7 NV	1043979	.33	.70	.94	--	.57	1.42	--	1.42	2.55	3.98	(3.47)

All data is 1980-81 except the sampled data from NV which is 1981-82 data.

Table F2

## Universities' Housing Costs Provided to CERL

Region (BOMA)	State	Building Area (Sq ft)	Administrative	Janitorial	Building Maint.	Renewal/ Replacement	Grounds Maint.	Gas	Electricity	Other Energy	Total O&M	
2	IA	1252426	.11	.78	.42	--	--	--	.38	.62	.05	2.36
3	IL	1259871	.51	--	.71	.21	.06	--	.33	.51	.15	2.48
3	IL	2285834	.11	.95	.51	.31	.05	All utilities	.91	--	2.84	
3	IN	3498520	.08	.52	.38	.22	--	.03	.35	.28	.08	1.94
4	WA	1201191	.54	.90	.45	.44	--	--	.10	.32	.08	2.83
6	AL	482057	.29	.16	.35	--	--	.11	.47	--	.06	1.44
6	GA	1246676	.90	.95	.16	.02	--	.03	.33	.21	.03	2.63
6	SC	1045652	.10	.62	.70	.16	--	All utilities	.56	--	2.14	
6	VA	733870	.29	.62	.73	.17	--	.31	.25	--	2.37	

APPENDIX G  
Summary of Municipalities' O&M Costs

Nine municipalities provided O&M cost data. However, one could not exclude costs for hospital and coliseum areas and one could not provide energy costs -- these two were not used. Table G1 presents the data for seven cities. Two of these were not used further as they appear to be extreme cases.

The accounting systems used by cities precluded a breakout of costs by type of cost.

Table G1

Summary of Municipalities' O&M Costs (\$/Sq Ft)  
(One city per state)

Area (sq ft)	AL	CA	IN	LA	MO	PA	TX
	794806	1012900	776410	502528	1152680	609000	363600
Administrative	\$1.32	.06	.38	.93	--	.55	.81
Janitorial	\$.59	.45	.72	1.07	.29	.50	2.50
Bldg Maint	\$.14*	.65	1.28	.76	.37	--	.17
Renewal/ Replacement	\$.06	.25	--	--	2.56	--	--
Gas	\$.09	Unk	.05	.16	.50	.46	.07
Electricity	\$.58	Unk	.91	.46	.27	.52	2.00
Total	\$2.78	1.41**	3.34	3.38	3.99	2.03	5.55**

\* No maintenance personnel salaries included.

\*\*Not used in Table 1.

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Neathammer, Robert D.

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